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THE EFFECT OF A UNIFORM MAGNETIC FIELD ON ELECTRODELESS DISCHARGE IN A TUBE AND MEASUREMENT OF ELECTRONIC MOBILITY I. AIR

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ABSTRACT. Results of measurements of the percentage increase in the breakdown potential in a discharge tube filled with dry air and excited with a 50-cycles alternating voltage, under a uniform magnetic field and of the electronic mobility have been reported. Measurements are made for different pressures and under magnetic fields inclined at different angles with the electric field Results are discussed from the standpoint of the theory proposed by Deb and Goswami (1956).

INTRODUCTION

The change in the values of the discharge current in both an ozoniser and an electrodeless discharge tube under the influence of a uniform magnetic field has been observed previously by several workers, viz., Bhiday *et al.* (1951) and Goswami (1954). In the course of further study with electrodeless discharge in a tube of simple geometry, it was recently reported by Deb and Goswami (1956) that in the range of pressures investigated, the value of the breakdown potential was always increased in the presence of a unifrom magnetic field. Experimental values of the breakdown potential, both with and without a superimposed magnetic field, were given, and a theory, based on electron ballistics, was presented to explain the increase in the value of the breakdown potential An expression for the electronic mobility was derived therefrom when the angle between the electric and magnetic fields was $\frac{\pi}{2}$. The value of the electronic mobility at a pressure of 1 mm Hg. thus calculated, agreed in order of magnitude with that given earlier by Brose. In this paper, measurements of the breakdown potential at different pressures, with and without a superimposed magnetic field, at different inclinations with the electric field, have been made, and values of electronic mobility obtained. The measurements have been repeated for several values of the magnetic field. The values of electronic mobility and its nature of variation with pressure agree fairly with those of Brose (1925) and Nielsen and Bradbury (1936, 1937).

EXPERIMENTAL

The discharge system used was one of the simplest possible geometry *e.g.*, a cylindrical tube (figure 1). An arrangement for revolving the discharge tube

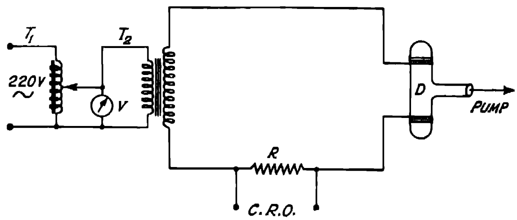

Fig. 1

about an axis perpendicular to its own and passing through its centre was provided in order to vary the inclination of the magnetic field with respect to the electric field. The tube was filled with dry air and was subjected to electrodeless discharge —the discharge being excited with 50 cycles alternating voltage obtained from the secondary winding of a step-up transformer T_2 The transformer primary was fed by the output of a variac T_1 which enabled one to smoothly vary the applied potential The pressure was reduced by means of a Cenco-hyvac pump and was recorded with a vacuoscope The magnetic field was obtained from an electromagnet with adjustable pole-pieces The wave-form of the discharge current was observed by applying the potential drop across a resistance R connected in series with the discharge circuit to the deflecting plates of a cathode-ray oscilloscope. Observations were made over the range of pressure 0.3 3.0 mm Hg, a range of exciting potential 0.45—4.06 KV(R.M.S.), and for magnetic fields 1575, 2000, 2475, 2950, 3175 and 3400 gauss.

The distance between the pole-pieces of the electromagnet was kept fixed at 4 3 cm. In making a set of observations, the discharge tube was first adjusted at a certain angle with the magnetic field, which was set at the desired value by varying the current in the electromagnet The pressure was next adjusted to a suitable value and with the magnetic field switched off the applied potential was gradually increased till pulses of discharge current just appeared on the screen of the oscilloscope The corresponding applied potential was noted. The magnetic field was then switched on and the new value of the applied potential at which the current pulses appeared again was noted The measurements were repeated for different values of pressure The discharge tube was next adjusted at a different angle with the magnetic field and in this new position similar measurements were carried out.

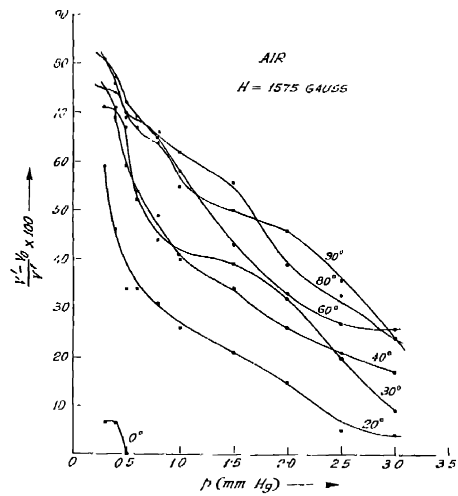
AIR
H = 1575 GAUSS
90°
80°
60°
40°
30°
20°
0°
p (mm Hg)
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
30
20
10
60
50
40

Fig. 2

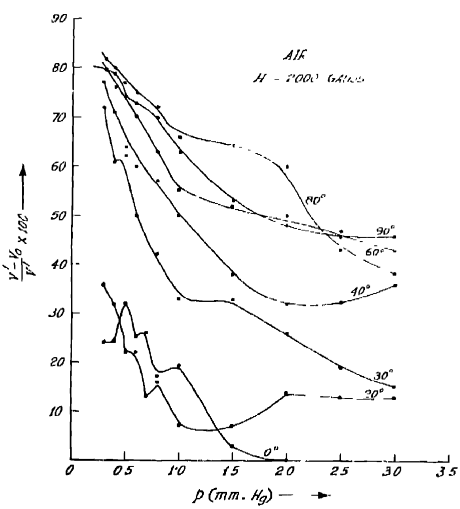
90
80
70
60
50
40
30
20
10
80°
90°
60°
40°
30°
20°
0°
p (mm. Hg)
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5

Fig. 3.

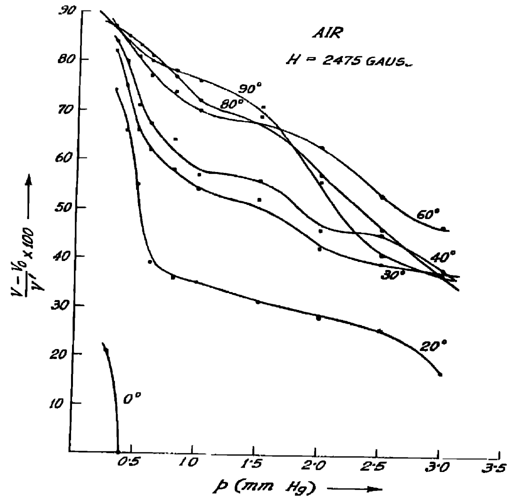
AIR
H = 2475 GAUSS
90°
80°
60°
40°
30°
20°
0°
$\frac{V-V_0}{V'} \times 100$
p (mm Hg)

Fig. 4.

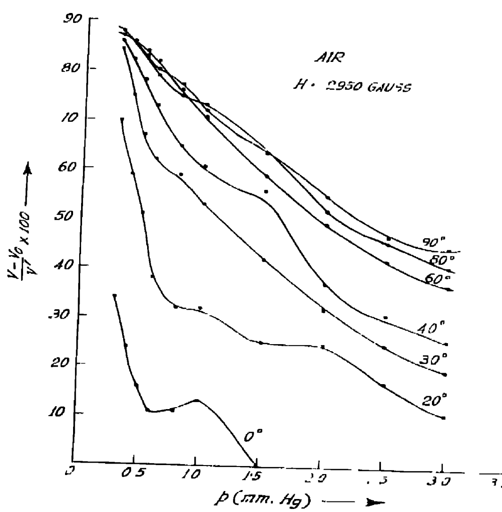
AIR
H = 2950 GAUSS
90°
80°
60°
40°
30°
20°
0°
$\frac{V-V_0}{V'} \times 100$
p (mm. Hg)

Fig. 5.

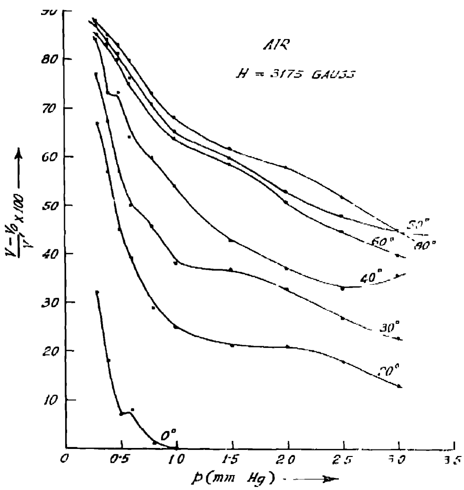
AIR
H = 3175 GAUSS
$\frac{V-V_0}{V} \times 100$
90°
60°
80°
40°
30°
20°
0°
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
10
20
30
40
50
60
70
80
90
p (mm Hg)

Fig. 6

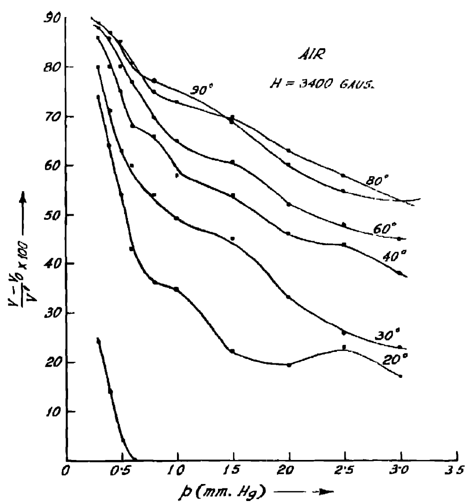
AIR
H = 3400 GAUS.
$\frac{V-V_0}{V} \times 100$
90°
80°
60°
40°
30°
20°
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
10
20
30
40
50
60
70
80
90
p (mm. Hg)

Fig. 7

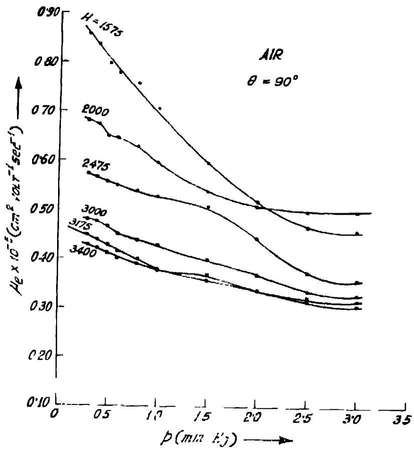

Fig 8

DISCUSSION OF RESULTS

The results obtained are shown in figures 2–8. On an examination of the curves the following facts may be summarised :

(i) The percentage effect $\frac{V'-V_0}{V'} \times 100$ diminishes with increase in pressure.

(ii) The percentage effect is, in general, higher for higher values of θ, the angle between electric and magnetic fields.

(iii) Electronic mobility decreases with increase of pressure.

(iv) Electronic mobility at a given pressure is less, the higher the magnetic field.

These observed facts receive simple explanation in the light of the theory given already in a previous communication (Deb and Goswami, 1956) where ϕ and μ_e are shown to be

$$\phi = \frac{He\lambda}{m\bar{v}c} \qquad \ldots \quad (1)$$

$$\mu_e = \frac{\cos^{-1}\left[1 - \frac{V'-V_0}{V'}\right]}{H} \times 10^8 \text{ cm}^2/\text{volt. sec.} \qquad \ldots \quad (2)$$

and
$$\frac{V'-V_0}{V'} = 1 - \cos\phi \qquad \ldots \quad (3)$$

When the angle between the electric and magnetic fields is θ, Eqns (1) and (2) take the form

$$\phi = \frac{H \sin\theta \cdot e\lambda}{m\bar{v}c} \qquad \ldots \quad (4)$$

and

$$\mu_e = \frac{\cos^{-1}\left[1 - \frac{V' - V_0}{V'}\right]}{H \sin\theta} \times 10^8 \text{ cm}^2/\text{volt sec} \qquad \ldots \quad (5)$$

As the pressure is increased, λ diminishes and it follows from Eqn. (4), that, for given values of H and θ, ϕ will decrease. This is in agreement with (i) above. Again from (4) it follows that other things remaining the same ϕ must increase with θ which explains (ii). The observed decrease in μ_e with increasing pressure [as in (iii) above] is also in agreement with the theoretical relation given by Nielsen & Bradbury (1936). Further, the higher is the magnetic field the greater is the proportion of total energy appearing as the lateral component and this brings about an apparent dependence of μ_e on H as noted under (iv) above. It is to be noted that the true value of μ_e is obtained only for very small values of H.

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